
Fracture Mechanics Modeling of Explosives

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Engineering Analysis

Engineering Analysis ————— Los Alamos National Lab —————

Explosives Research Program Review

Fracture in Explosives

- Fracture is Significant
 - Geometry
 - Stress State
- Finite Element Model of Discrete Fracture
- Mechanically Coupled Cook Off

Discrete Fracture Model

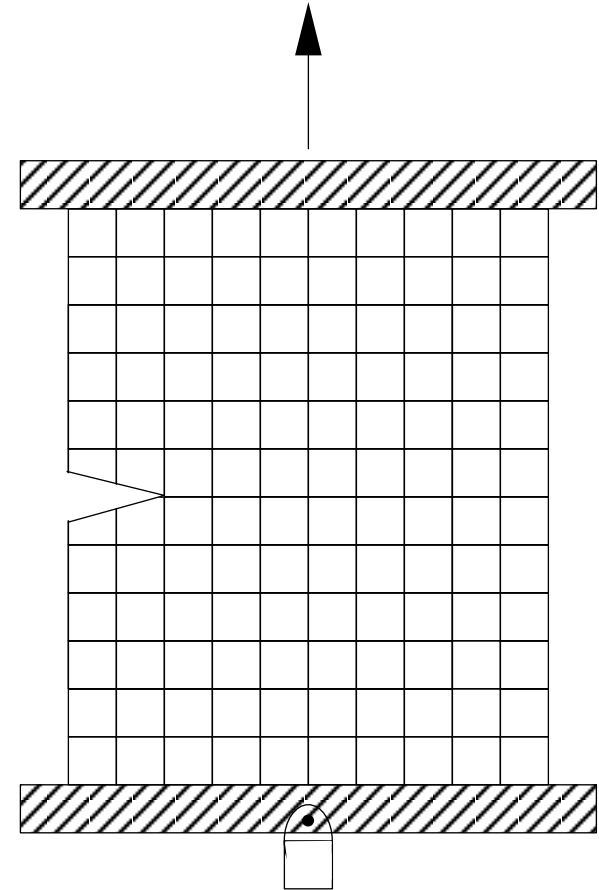
- Model Dynamic Behavior of Cracks in Structures
 - Crack Propagation/Surface Creation
 - Stress Concentration
 - Fragmentation - Many Cracks
- Maintain Original Fidelity
 - Don't Delete Elements
 - Don't Reduce Stiffness

Discrete Fracture Model

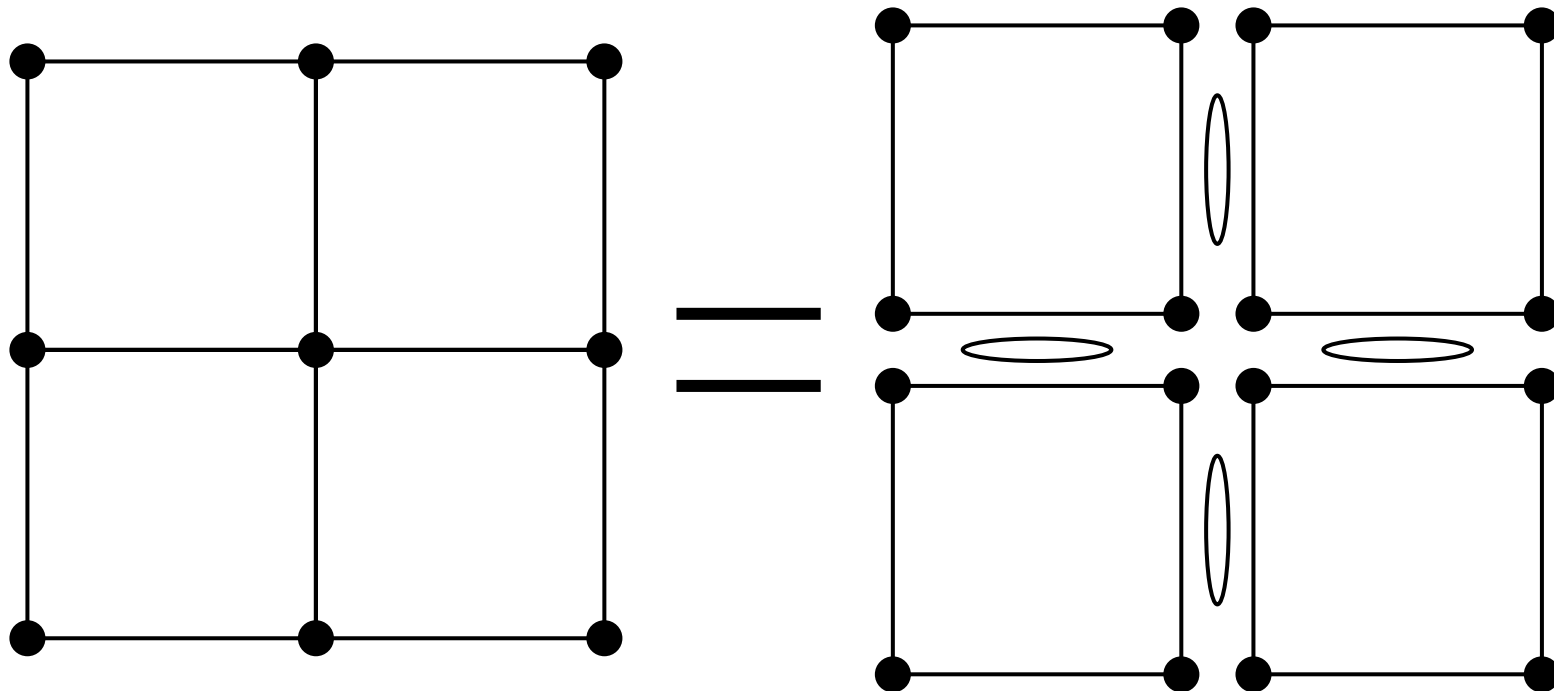
- 2 Dimensional
- Explicit - DYNA3D
 - Short Time Events
- Implicit - ABAQUS/Standard
 - Short to Long Time Events
- Similar Discrete Fracture Models

Discrete Fracture Model

- Cracks Propagate Along Element Interfaces
- Unique Nodal Connectivity for Each Element
 - Maintain Nodal Connectivity
 - No Remeshing

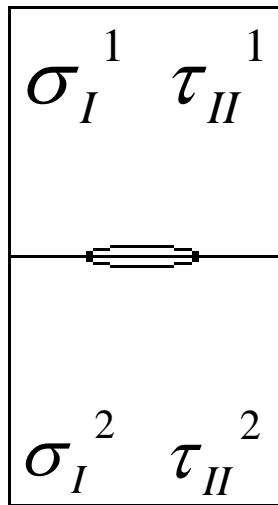


Discrete Fracture Model



Discrete Fracture Model

- Interface Failure



$$\sigma_I = \frac{\sigma_I^1 + \sigma_I^2}{2}$$

$$\tau_{II} = \frac{\tau_{II}^1 + \tau_{II}^2}{2}$$

Discrete Fracture Model

- Elastic Plastic Crack Growth

$$K_I = \sigma_I \sqrt{\pi \cdot a} \quad K_{II} = \tau_{II} \sqrt{\pi \cdot a}$$

$$G = \frac{K_I^2 + K_{II}^2}{E}$$

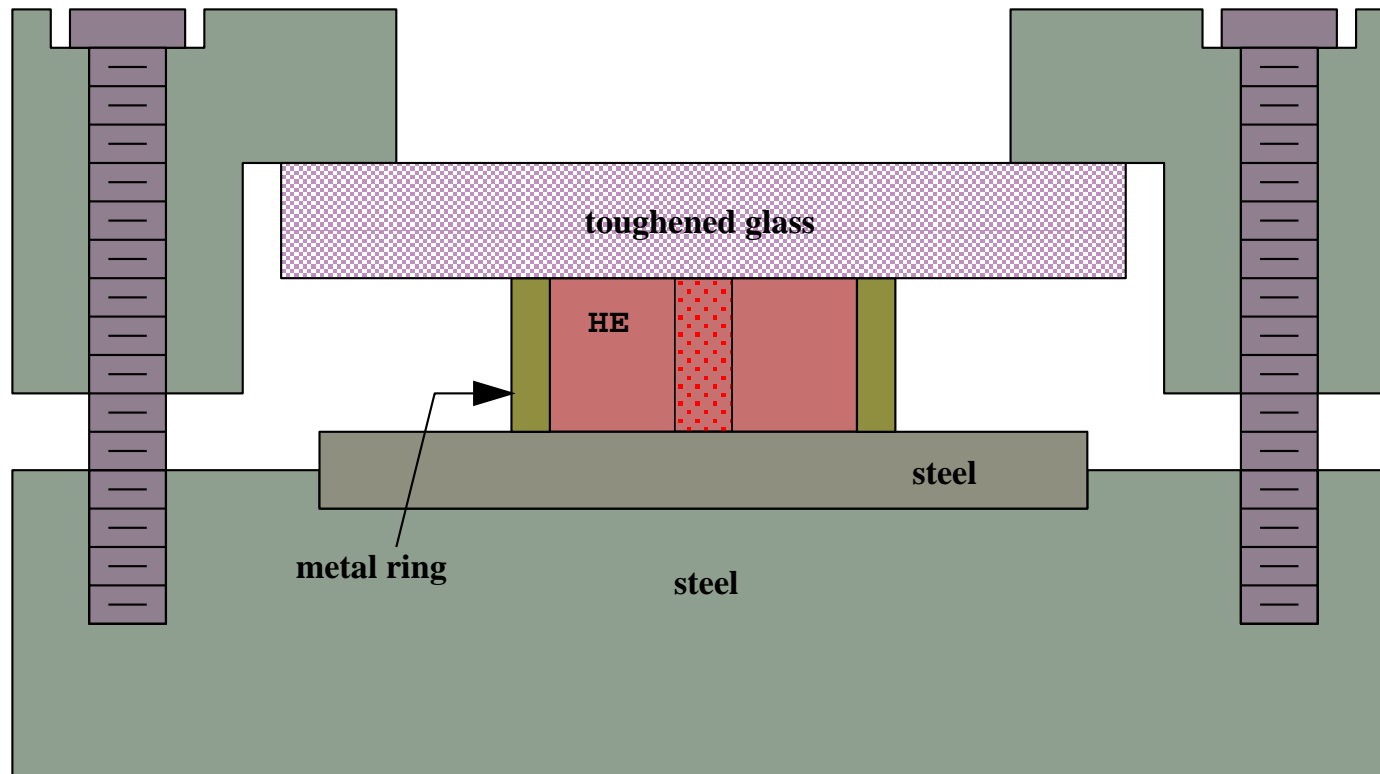
$$G = \beta (\Delta a)^\gamma + \lambda \quad \Delta a = \left(\frac{G - \lambda}{\beta} \right)^{\frac{1}{\gamma}}$$

- If $(a + \Delta a) > \text{width}$ - Interface Fails

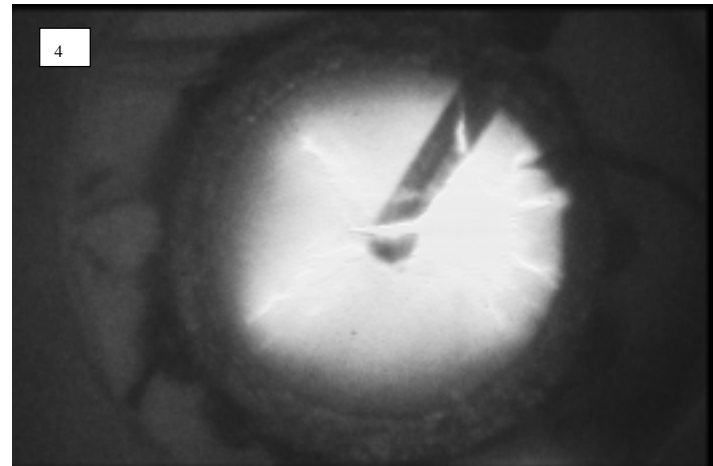
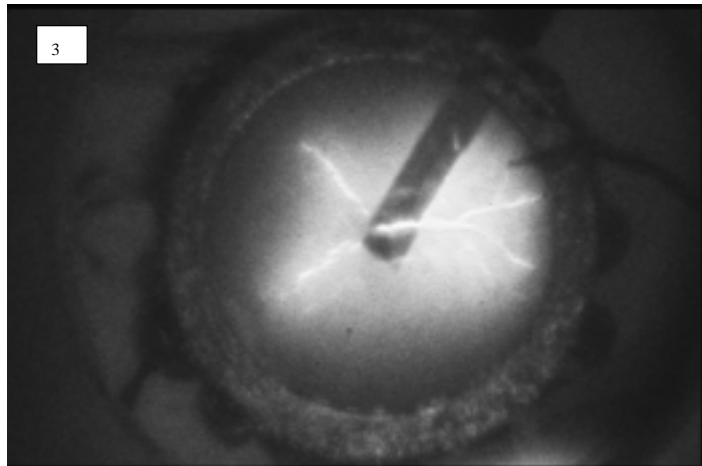
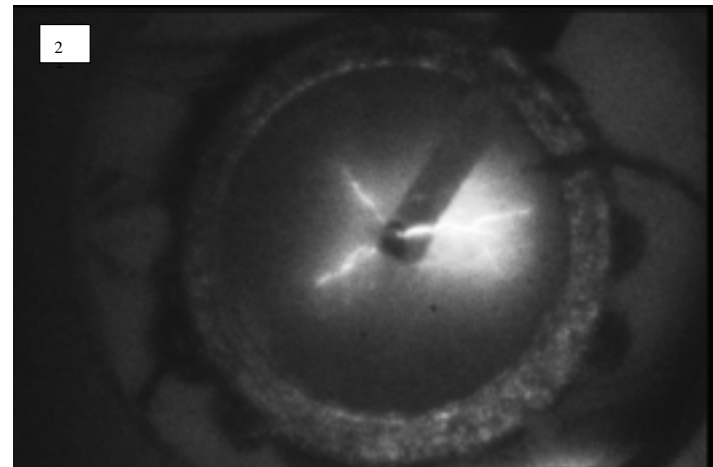
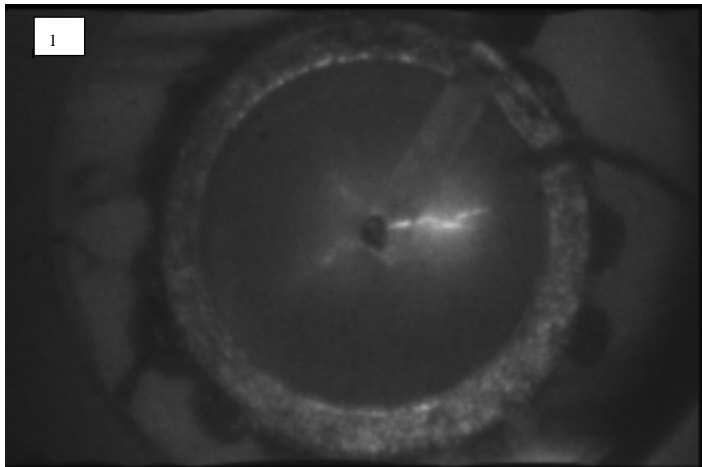
Fracture Model - PBX 9501

- Difficulties
 - Mechanical Behavior of HE is Very Complex
 - Non-Linear
 - Temperature Dependant
 - Non-Continuous
 - Limited Fracture Data
 - Need $G(\Delta a)$

Mechanically Coupled Cook Off



Mechanically Coupled Cook Off



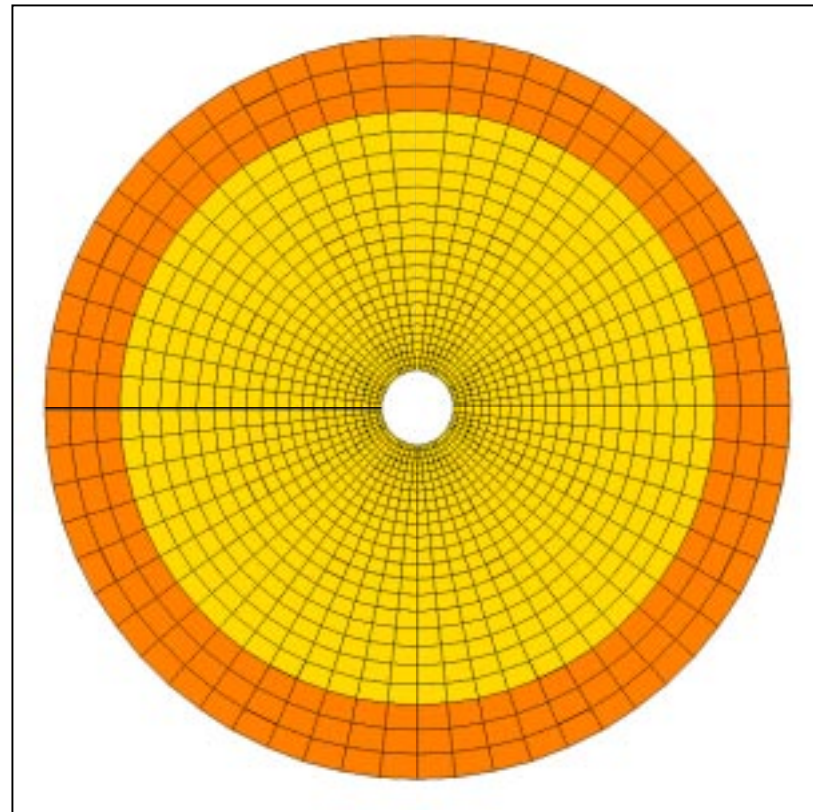
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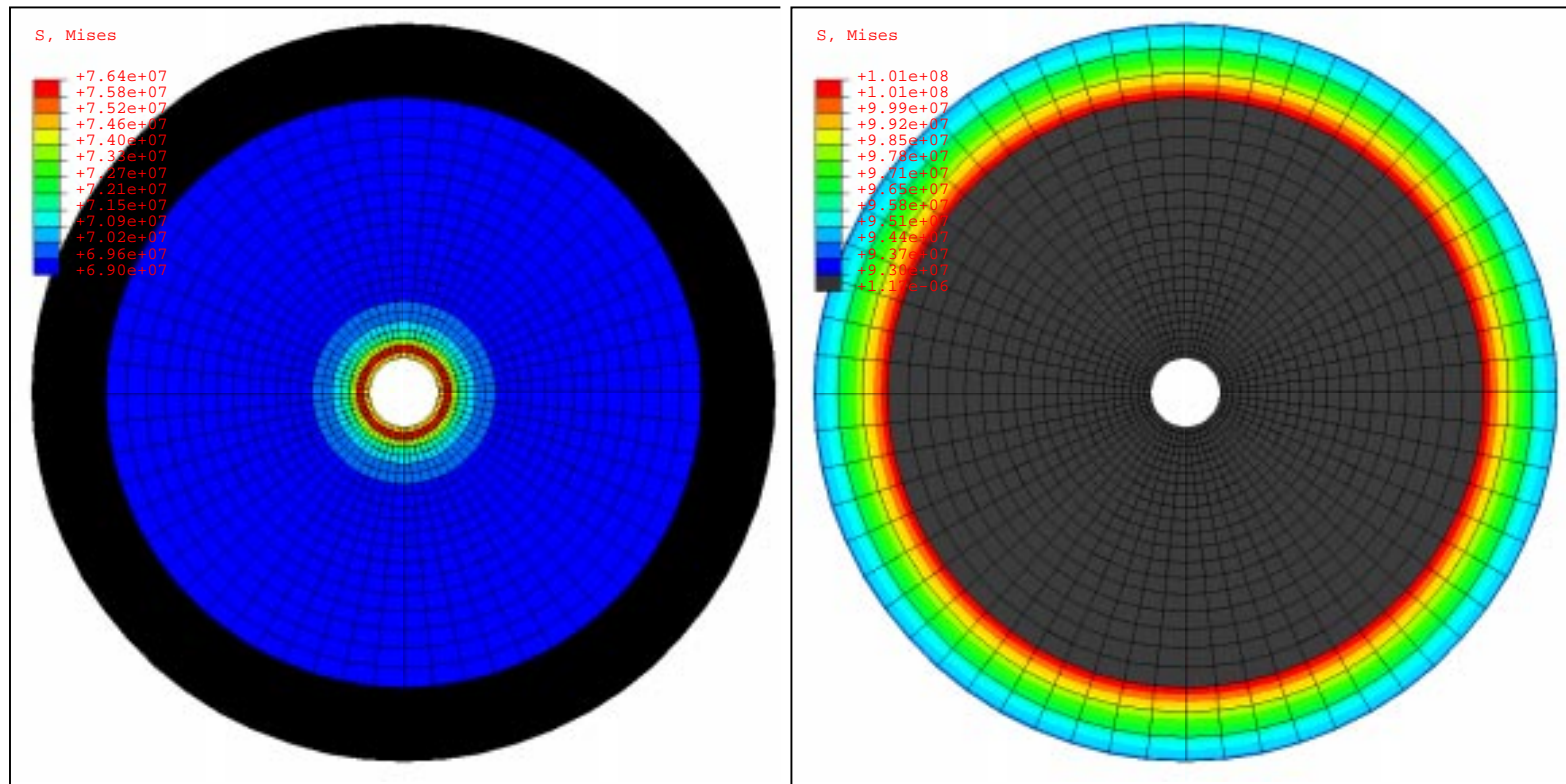
Mechanically Coupled Cook Off

- In
 - Implicit
 - Plane Strain
 - Random Cracks
 - Elastic/Plastic Cu
 - ViscoSCRAM
 - Thermal Expansion
- Out
 - Stress Bridging
 - Conduction
 - HE Burn
 - Temp. Dependence



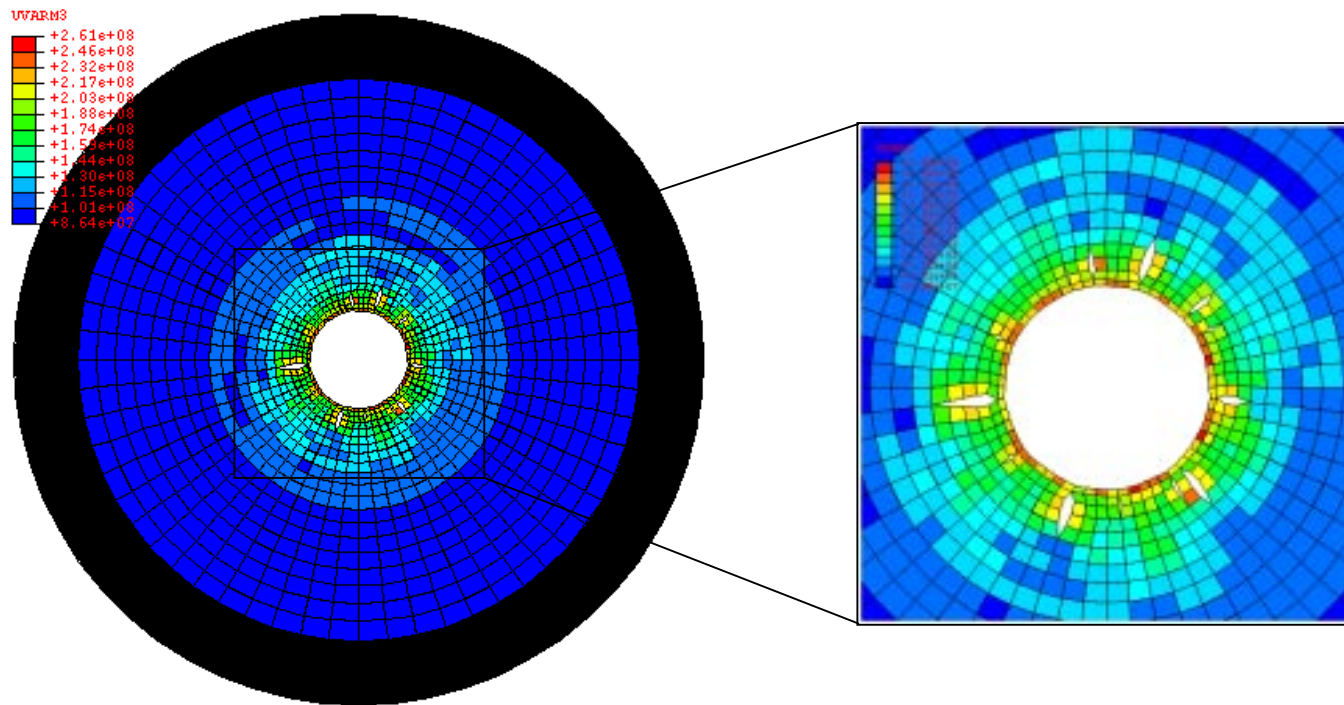
Mechanically Coupled Cook Off

- Heat Up 120 K



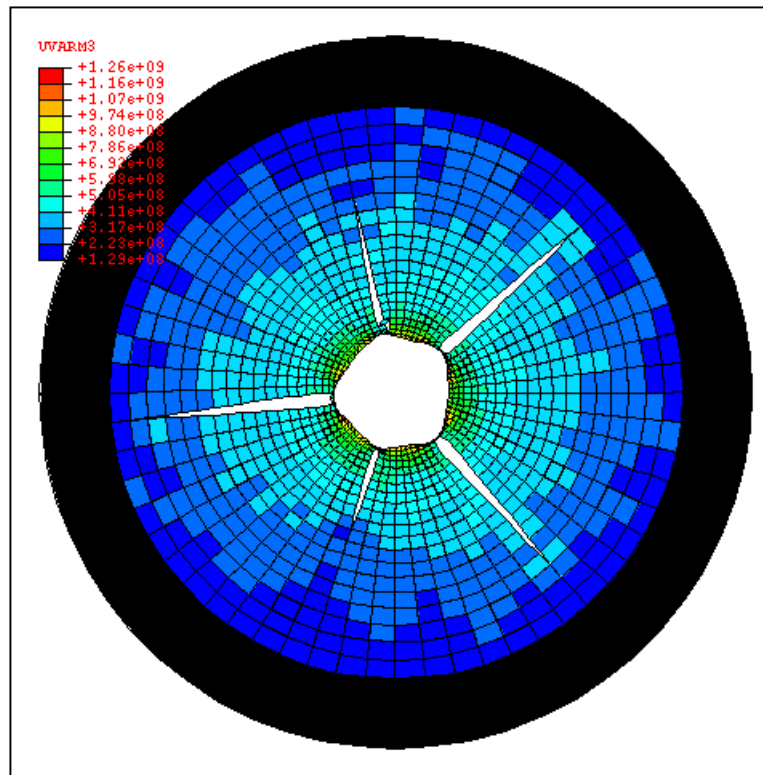
Mechanically Coupled Cook Off

- Apply Pressure - 5MPa/ μ sec



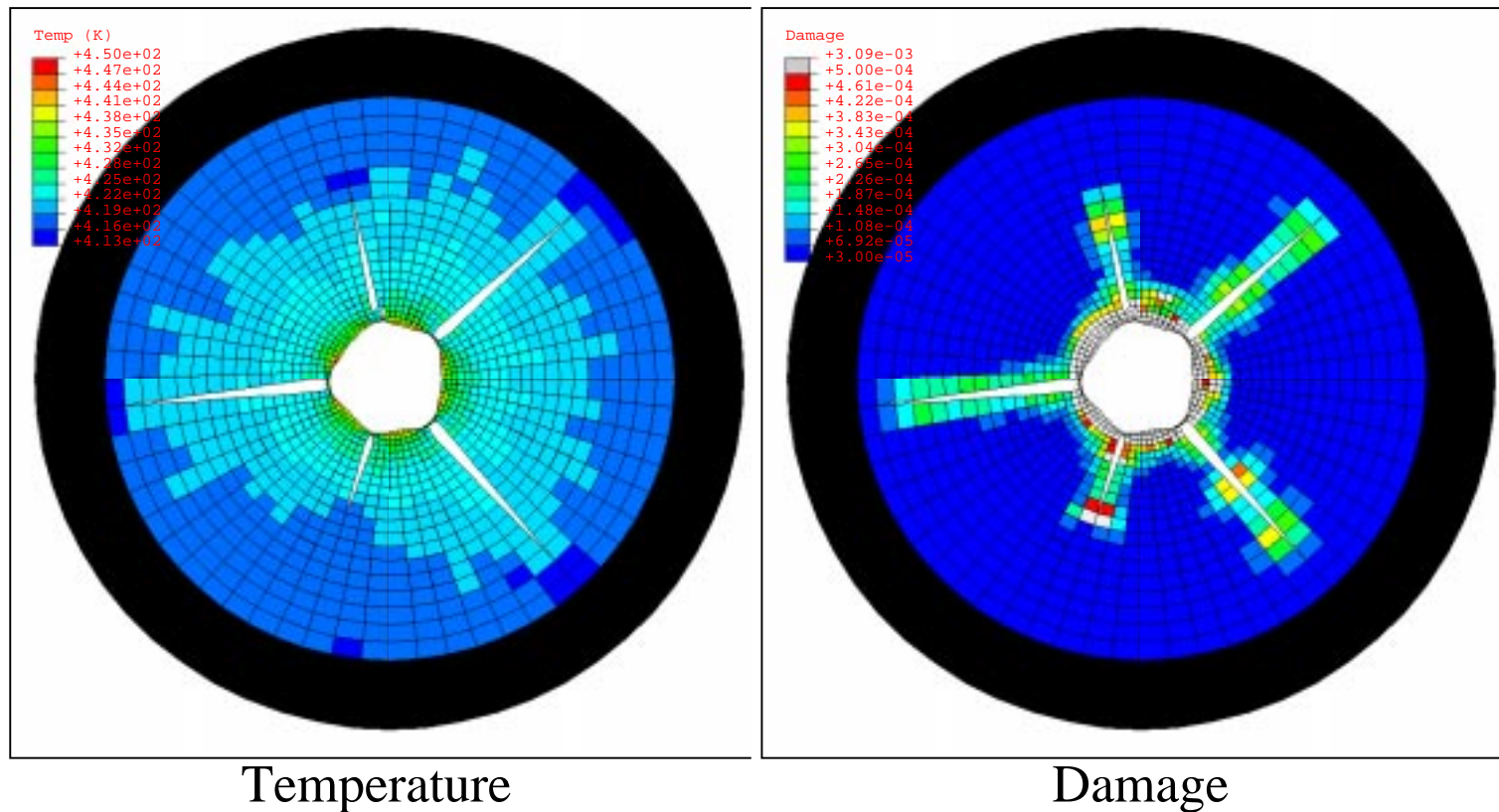
Mechanically Coupled Cook Off

- 3 to 5 Large Discrete Cracks



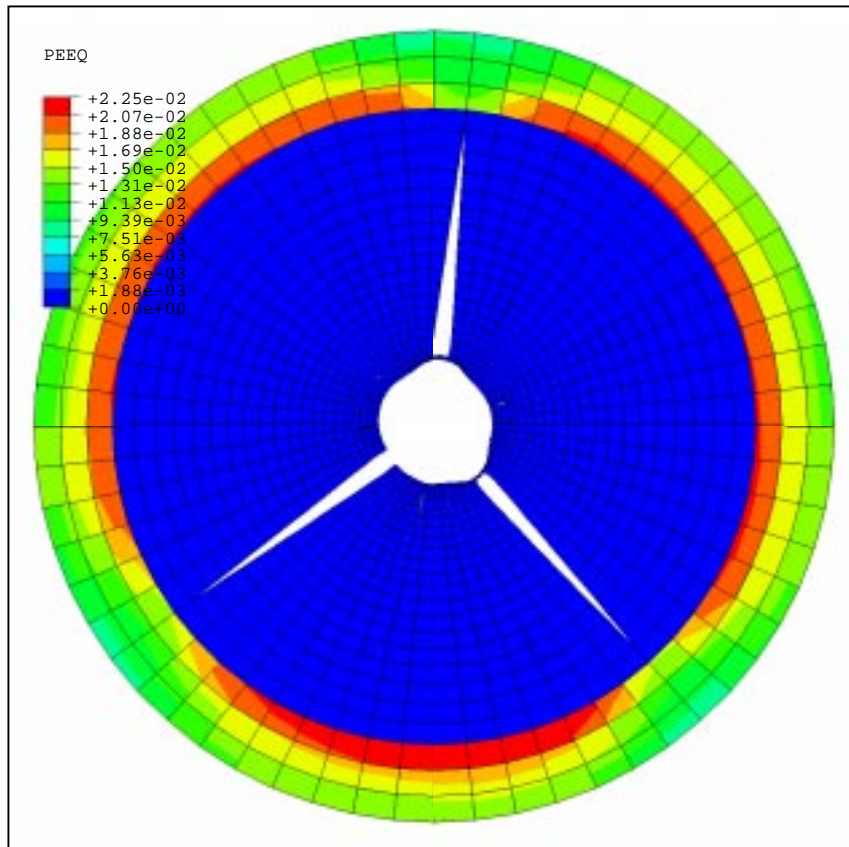
Mechanically Coupled Cook Off

- Cracks Increase Temp. and Damage



Mechanically Coupled Cook Off

- Strain In Ring
 - Didn't Compare
 - High Plastic Strain
 - Significant Radial Variation



Conclusions

- We Can Model Discrete Fracture In HE